Eur J Orthop Surg Traumatol (2018) 28:317–323
https://doi.org/10.1007/s00590-017-2048-z

Combined avulsion fracture of the tibial tubercle and patellar tendon rupture in pediatric population: case series and review of literature

Mohamed Abdelhamid Ali Yousef[1]

Received: 11 July 2017 / Accepted: 10 September 2017 / Published online: 27 September 2017

Abstract Simultaneous occurrence of tibial tubercle fracture and patellar tendon avulsion with double-hit injury of the knee extensor mechanism is an extremely rare condition. However, they become more frequent due to increased participation in sports and high-energy recreational activities at younger age. It represents a frequently missed diagnosis; therefore, high index of suspicion is required for the diagnosis of such injuries to avoid delays in the treatment which would lead to possible suboptimal functional outcome. Only few case reports of such injuries were reported in the literature with limited information regarding frequency, diagnosis, and outcome in children. To the best of our knowledge, this is the first case series with such type of injury.

Keywords Knee injuries · Double-hit injuries · Knee extensor mechanism injury

Introduction

Avulsion fractures of the tibial tubercle are rare injuries in pediatric population and represent less than 1% of all physeal fractures [1]. It results from violent eccentric contraction of the quadriceps muscle. In the pediatric population, the physis is the weakest link that exists among the muscle–tendon-bone complex. For this reason, an avulsion fracture is much more likely to occur than a tendon rupture. The association of tibial tubercle avulsion fracture with patellar tendon avulsion is extremely rare. Only few case reports of such injuries [2–8] have been reported in the literature with limited information regarding frequency, diagnosis, and outcome in children. Although rare, it is considered a serious injury that necessitates prompt diagnosis and early surgical repair. We present 3 cases of tibial tubercle fractures with simultaneous avulsed patellar tendon who were treated at our institution.

Patients and methods

After approval by the institutional review board, a retrospective review of patients' medical records who sustained acute traumatic injury of the knee extensor mechanism and presented for treatment at our level I pediatric trauma center was performed. Three patients with simultaneous tibial tubercle fractures and avulsed patellar tendon were identified. Demographic data retrieved included age at time of surgery, sex, side involved, mechanism of injury, and follow-up duration. Tibial tubercle fractures were described according to Ogden classification [9]. Associated knee injuries, complications and the presence or absence of Osgood–Schlatter disease were noted. Patellar displacement ratio was calculated on the preoperative lateral X-ray while the knee in 60° flexion by dividing the length of a line connecting the lower pole of the patella to the avulsed tibial tubercle fragment over the length of a line connecting the upper and lower poles of the patella. Surgical technique, method of patellar tendon fixation, and the period of postoperative immobilization were reviewed. The total duration of physiotherapy and time to return to daily activities were recorded. The functional outcome was evaluated regarding the knee active range of motion (AROM) and the presence or the absence of

✉ Mohamed Abdelhamid Ali Yousef
mayousef@texaschildrens.org

[1] Department of Orthopaedic Surgery, Texas Children's Hospital, 6701 Fannin St. Suite 660, Houston, TX 77030, USA

terminal extension lag. Radiographic outcome was evaluated regarding the presence of fracture healing or implant-related complication.

Case 1

A 13-year-old male injured his left knee while he was going up for a layup and felt a pop in his knee on his way out during playing basketball. He was unable to bear weight on his injured extremity after the injury. On examination, he had pain over the anterior portion of the knee with palpation, especially over the tubercle and patellar tendon area with large knee effusion. Lachman test was negative, and there was no varus and valgus instability of the knee. He had very limited range of motion. No relevant medical history was identified. Knee X-ray showed tibial tubercle avulsion fracture type IB according to Ogden's classification. Patellar displacement ratio was calculated to be equal 1.5 (Fig. 1). No Osgood–Schlatter disease was noted.

Under general anesthesia, the anterior approach was made to the tibial tubercle using a lateral parapatellar incision. While exposing the tendon and the fragment, it became apparent that the tendon was completely avulsed from the tubercle fragment. The fragment was removed and placed in saline. No. 2 FiberWire was placed in Krackow fashion within the patellar tendon with placing 1 suture laterally and 1 suture medially resulting in 4 suture tails holding the patellar tendon. A scalpel was used to make a small hole in the base of the patellar tendon, which seemed to have a nice fibrous attachment where it had avulsed from the fragment. The avulsed tibia tubercle fragment was put back into the wound and fixed with a partially threaded screw. The screw was inserted with a derotation pin in the tendon and the fragment over a spiked washer. Then a 2-mm hole was placed in the anterior tibial cortex from lateral to medial through which the suture tails were brought through with the help of suture passer. The sutures were tied with the knee in full extension. Stable fixation was achieved with the knee being flexed easily past 90° with intact fixation. Long-leg cylinder cast was applied with the knee in full extension for 3 weeks. Postoperative X-ray was performed (Fig. 2) showing good fragment fixation.

After 3 weeks, incision was healed well with the presence of peri-incisional numbness. Significant atrophy of quadriceps muscle was observed. The cast was removed and replaced by hinged knee brace locked in extension for walking, and the patient was instructed to unlock the brace and allow some range of motion as quadriceps muscle got stronger. At this point, the patient was allowed to start physical therapy.

At 8 weeks, the patient was able to complete straight leg raise without extensor lag; therefore, brace was discontinued. Significant quadriceps atrophy with minimal contraction was noted when compared to the other side. Limited patellar mobility was also observed. Peri-incisional numbness was still present.

Fig. 1 Preoperative plain X-ray of the knee with lateral view showed displaced tibial tubercle avulsed fragment type I according to Ogden classification with calculated patellar displacement ratio

At 12 weeks, knee AROM was 0°–130°. There was no knee effusion or pain with squatting. At this point, complete healing of the fracture was detected with stable implant. There were multiple calcifications along the inferior and posterior aspects of the patellar tendon extending to the level of the patella (Fig. 3). At this time, the patient returned to his normal activities; however, he continued to attend the physical therapy sessions at the hospital for 21 weeks for sports-specific training.

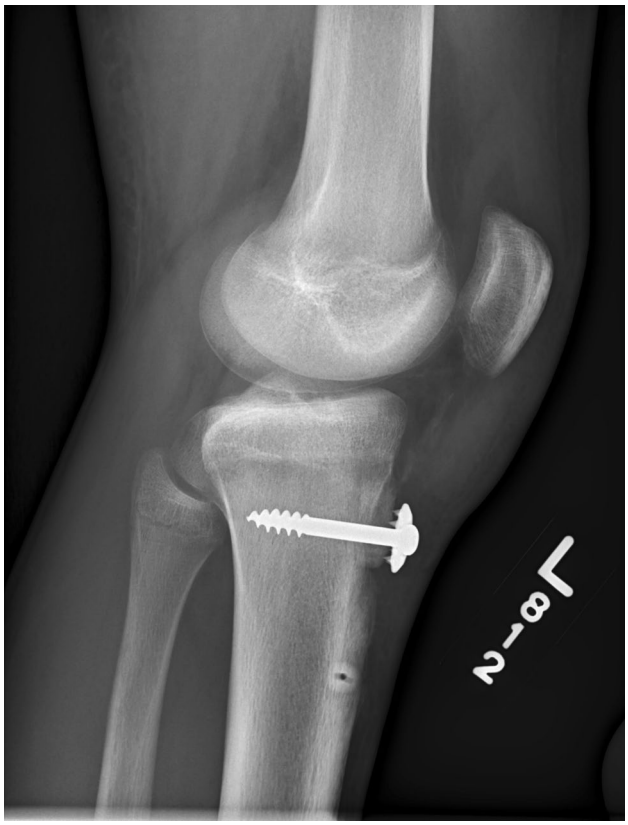

Fig. 2 Postoperative plain X-ray of the knee with lateral view showed good fragment fixation

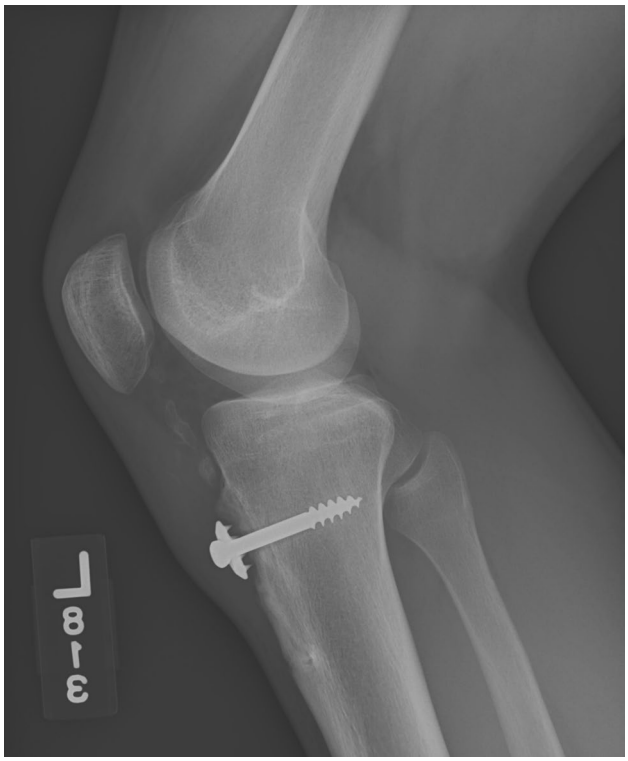

Fig. 3 Postoperative plain X-ray of the knee with lateral view at the final follow-up visit showed good patellar position with multiple calcifications along the line of the patellar tendon

Case 2

A 14-year-old male injured his left knee while he was jumping while playing basketball and felt severe pain in his knee. The patient was unable to bear weight immediately after the injury. On examination, there was marked tenderness with palpation, especially over the tibial tubercle and patellar tendon area with large knee effusion. Lachman test was negative, and there was no varus and valgus instability of the knee. No relevant medical history was identified. Knee X-ray showed tibial tubercle avulsion fracture type IIIB according to Ogden's classification, and the patellar displacement ratio was 1.4. No Osgood–Schlatter disease was noted.

Under general anesthesia, an approximately 10-cm incision was made over his anterior knee from the distal pole of the patella to the tibial tubercle. The fracture site was identified and then copiously irrigated. Patellar tendon avulsion was identified. At this point, an arthrotomy incision was made and the capsule was dissected down into the joint until the proximal tibial plateau could be visualized and palpated digitally. After that, a towel clip was placed to manipulate the avulsed tibial tubercle fragment to reduce the fracture. C-arm fluoroscopy was used to confirm adequate reduction with no intraarticular step-offs. At this point, 2 guide pins were used to provisionally fix the fracture. They were placed from an anterior to posterior direction through the epiphysis of the proximal tibia. C-arm fluoroscopy confirmed good placement and reduction of the fracture. Two cannulated screws were then placed over the guide pins. Again, C-arm fluoroscopy was used to confirm reduction and adequate placement of screws. At this point, the guide pins were taken out and attention was focused to the avulsed patellar tendon. Two Mitek No. 0 QuickAnchor (DePuy Synthes, USA) were used and placed into the proximal tibial shaft after pre-drilling (Fig. 4). The patellar tendon was then sewn down to the tibia using Krackow suture technique. The skin was closed over a drain which was removed after 36 h. A locked knee immobilizer was placed to maintain the knee in full extension for 3 weeks. After 3 weeks, incision was healed well and he was allowed to flex his knee by 20° or 30° using a hinged knee brace.

At 8 weeks, the knee immobilizer was discontinued. He was able to actively flex the knee to 90°. Quadriceps atrophy was noted with 3/5 strength. At this point, physical therapy was initiated. Complete healing of the fracture was noted with stable implant.

Fig. 4 Postoperative plain X-ray of the knee with lateral view showed fracture fixation with 2 screws. It also showed two suture anchors used for reattachment of the patellar tendon

At 20 weeks, knee AROM was 0°–130° without terminal extension lag. At this point, the patient returned to his daily activities.

Case 3

A 14-year-old male injured his bilateral knees when he felt on the sidewalk while running. The patient was unable to bear weight immediately after the injury on both extremities. On examination, there was marked tenderness with palpation, especially over the tibial tubercle with large knee effusion detected bilaterally. Lachman test was negative, and there was no varus and valgus instability of both knees. No relevant medical history was identified. Knee X-ray showed tibial tubercle avulsion fracture type IIB according to Ogden's classification on the right knee and tibial tubercle avulsion fracture type IIB according to Ogden's classification on the left knee (Fig. 5). The patellar displacement ratio was 1.3 and 1.6 on the right and left knees, respectively.

Under general anesthesia and bilateral femoral blocks, surgery was performed on both knees. Regarding the right knee, a 10-cm anterior incision was made. Dissection was carried down till the avulsed tibial tubercle was identified which was still connected to the patella ligament. At this point, the fracture was reduced and fixed with 2 screws with the use of washer for the distal one. Good reduction was confirmed with the use of fluoroscopy. Regarding the left knee, a second 10-cm incision was made. Dissection was carried down till the injured area was identified. At this point, complete avulsion of the patellar tendon from the tibial tuberosity was noted; in addition, the tibial tuberosity was also found to be avulsed and free-floating in the surgical wound. At this point, the tibial tubercle was taken out and reserved on the surgical table as irrigation and

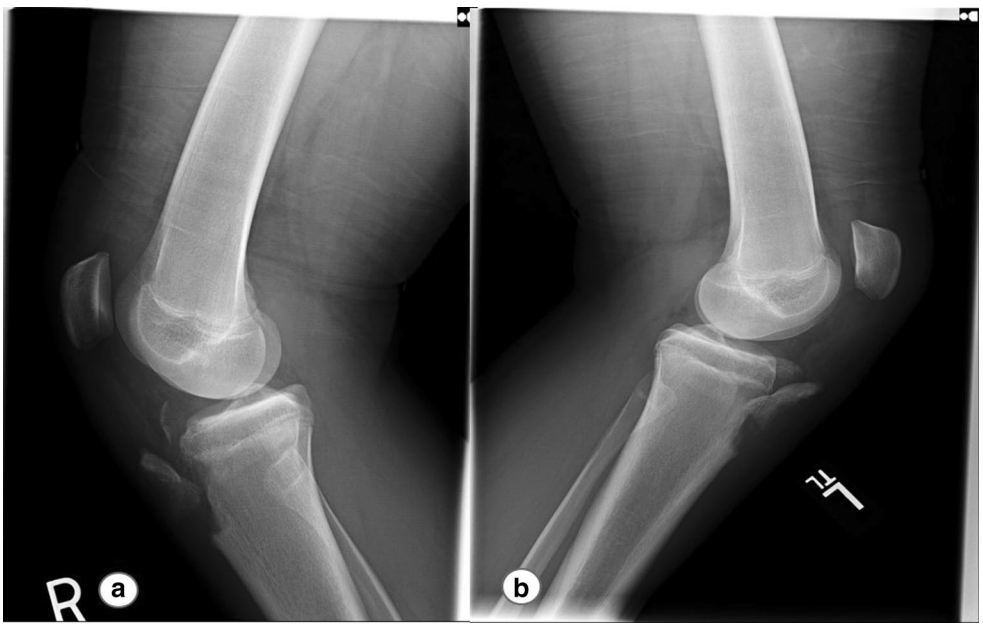

Fig. 5 Preoperative plain X-ray of the right knee (**a**) and left knee (**b**) with lateral view showed displaced tibial tubercle avulsed fragment type II according to Ogden classification in both knees with higher patellar position on the left knee

curettage of the fracture site were performed. The fracture fragment was then placed back onto the anterior tibia with the use of guide pins, and the tibial tubercle fragment was fixed by 2 cannulated screws. Two distal tunnels were then drilled in a transverse fashion across the tibia, and No. 2 FiberWire was brought through these tunnels. Using the Bunnell suture technique, the 4 suture tails were passed up through the patella ligament and tied. Additionally, multiple ethibond sutures were used to repair the retinaculum and to repair the insertion of the patellar ligament on the proximal tibia.

Bilateral knee immobilizer was placed for 4 weeks. After 4 weeks, incision was healed well. Significant atrophy of quadriceps muscle bilaterally was observed. The patient was placed in Bledsoe hinged knee brace on the right knee. At this point, the patient was allowed to start physical therapy.

At 8 weeks, the left knee AROM was 0°–100° while the left knee AROM was 5°–85°. At this point, brace was discontinued and complete healing of the fracture was achieved bilaterally. The patient was instructed to continue the physical therapy.

At 12 weeks, full terminal extension was achieved bilaterally with 5/5 quadriceps muscle strength. The right knee AROM was 0°–125°, while the left knee AROM was 0°–120°. At 17 weeks, patient was allowed to return to sports activities. The patient attended the physical therapy sessions at the hospital for 28 weeks. Two years later, bilateral screws removal was performed due to palpable screw heads with mild pain.

Results

Among seventy-one pediatric patients who sustained acute traumatic injury of the knee extensor mechanism at our institution, 3 patients with combined distal patellar tendon rupture with tibial tubercle fracture (4.2%) were identified (Table 1). The diagnosis of patellar tendon avulsion was made depending on the intraoperative finding in all our cases, and no case was diagnosed before the surgery.

Discussion

Tibial tubercle avulsion fracture results from failure through the secondary apophysis which is specifically limited to the pediatric population and requires prompt diagnosis and early management. Although the occurrence of physeal fractures around the knee is relatively uncommon, they become more frequent due to increased participation in sports and high-energy recreational activities at younger age [10]. However, the simultaneous occurrence of tibial tubercle fracture and patellar tendon avulsion with double-hit injury of the knee extensor mechanism is an extremely rare condition.

The peak age of incidence for occurrence of such injury ranges between 13 and 17 years old, which is consistent with

Table 1 Summarized demographic, perioperative, and outcome data of the case series

	Case 1	Case 2	Case 3
Age	13	14	14
Sex	Male	Male	Male
Side	Left	Left	Left
Sports activity	Basketball	Basketball	Running
Follow-up duration	21 months	20 months	28 months
Ogden classification	IB	IIIB	IIB
Osgood–Schlatter disease	Not detected	Not detected	Not detected
Patellar displacement ratio	1.5	1.3	1.5
Associated knee injuries	No	No	No
Other morbidity	No	No	Contralateral tibial tubercle avulsion fracture
Complications	Peri-incisional numbness	No	No
Method of patellar tendon fixation	Transosseous suture + spiked washer	Suture anchors	Transosseous suture
Period of postoperative immobilization	3 weeks	3 weeks	4 weeks
Time to return to daily activities	12 weeks	20 weeks	17 weeks
Time of healing	12 weeks	8 weeks	8 weeks
Implant-related complication	No	No	No
Further surgery	No	No	Implant removal

the time of the secondary ossification and fusion of tibial tubercle apophysis with the epiphysis [7, 9]. Such injury pattern can be explained by the tibial tubercle development which is classified into 4 stages: (1) the cartilaginous stage which persists till the age of 11.5 years; (2) the apophyseal stage which starts by the age of 11.6 years in which the secondary ossification center begins to appear on the distal part of the cartilaginous homologue; (3) the epiphyseal stage which starts at the age of 13 years in which the ossification centers of the proximal tibial epiphysis and tubercle coalesce to form bone; and (4) the bony stage with closure of the epiphyseal growth plates by the age of 15 years in girls and 17 years in boys [11]. Certain histological changes occur during the stages of the tibial tubercle development. During the cartilaginous stage, the tibial tubercle growth plate is formed mainly of fibrocartilage with columnar cartilage only proximally near the proximal tibial epiphysis. As the tibial tubercle matures through transition into the apophyseal and epiphyseal stages, the fibrocartilage becomes progressively replaced with columnar cartilage in proximal to distal direction considering that fibrocartilage is resistant to tensile stress while columnar cartilage is a weak one; this explains why such injuries occur frequently in the transition from the epiphyseal stage to the bony stage which is known as physiological physiodesis where the tibial tubercle growth plate is mostly formed of columnar cartilage [11].

The mechanism of injury that resulted in avulsion of both the tibial tubercle and the patellar tendon is not clearly defined. Mayba [2], who was the first to report such injury in 1982, had proposed that violent continued contraction of the quadriceps muscle even after the fracture occurred, was responsible for such injury pattern. While Frankel [3] had shown that violent flexion of the knee in opposition to a hardly contracted quadriceps muscle while the foot is fixed, was the main cause for such injury, we think that the tibial tubercle bone fails first due to violent quadriceps contraction explained by the weak resistance of the growth plate during the period of physiological physiodesis which extends from 13 to 17 years old in boys then due to continued quadriceps contraction with either incompletely detached or incarcerated tibial tubercle bone fragment, subsequent avulsion of the patellar tendon occurs.

We believe the occurrence of such injury pattern had increased progressively due to increased participation of sports activities at younger age. Most of the reported injuries were related to the sports activities such as basketball [4], hurdling [7], and football [8]. In our series, all injuries occurred in association with sports activities such as basketball in 2 patients and running in one patient. Associated injury to the meniscus or cruciate ligaments had been demonstrated in some case reports [6, 8]. However, no associated injuries were detected in our series. The occurrence of such injury pattern was not associated with the pre-existing Osgood–Schlatter disease in our patients. No significant medical history was identified to predispose to such injury.

In such injury pattern, the reported associated tibial tubercle fracture was type II [7, 8] or type III [4, 12] according to Ogden classification which further divides each type by displacement and degree of comminution into A and B subtypes. In our series, the associated tibial tubercle fractures were types I, II, and III. It was interesting to find patellar tendon avulsion even in type I which has not been previously reported in the literature. Frankl et al. [3] had added subtype C for fractures associated with rupture patellar tendon.

The detection of patellar tendon avulsion in patients with tibial tubercle fracture is highly important as this directly impacts the management plan considering that non-displaced tibial tubercle avulsion fracture Ogden types I and II can be treated conservatively with plaster cast or by percutaneous reduction and fixation without the need for open surgery. The diagnosis of simultaneous ruptured patellar tendon, on the other hand, necessitates early open surgical repair. However, clinical diagnosis of such injuries can be challenging due to swelling and pain. High level of suspicion should exist in the presence of loss of active knee extension or palpable infrapatellar gap. Radiological assessment might be helpful to suspect the diagnosis of such injury. Frankel et al. [3] had shown that increased the distance between the distal pole of the patella and the avulsed tibial tubercle fragment with knee flexion raises the suspicion of simultaneous avulsed patellar tendon. Also, Kramer et al. [12] found that the presence of multiple calcified fragments below the patella can be a diagnostic clue of patellar tendon avulsion as they mostly represent avulsed tibial tubercle periosteum still attached to the distal patellar ligament. In our series, high displacement ratio was detected in all cases which can be a helpful diagnostic tool to predict a possible patellar tendon avulsion injury in association with the tibial tubercle fracture. The presence of multiple calcified fragments below the patella as a sign of patellar tendon rupture was not identified in any of our cases.

The treatment of such injuries consists of open reduction and internal fixation of the tibial tubercle fracture usually with compression screws in addition to surgical repair of the avulsed patellar ligament. The reinsertion of the patellar ligament was performed using staples [7], tension band [4], or transosseous suture [12]. In our series, we had variable method of fixation including transosseous suturing with spiked washer, suture anchors, and transosseous suturing alone. Using the suture anchor was associated with a relatively longer period to return to daily activity, while using transosseous suturing with spiked washer was associated with a shorter time to return to daily activities.

The reported period of postoperative immobilization in a long-leg cylindrical cast ranged from 4 weeks [7] to 6 weeks [12], while in our series, the duration of rigid knee

immobilization ranged from 3 to 4 weeks. The time required to regain full range of motion after such injury ranged from 3 months [7] to 5 months [8]. Similarly, the full range of motion was achieved between 3 and 5 months in our series.

Conclusion

Simultaneous occurrence of patellar tendon rupture and tibial tubercle fracture represents 4.2% of patients who sustained acute traumatic injury of the knee extensor mechanism. Although uncommon, the possibility of simultaneous occurrence of the patellar tendon avulsion and tibial tubercle fracture should be considered with increased participation in sports activities at younger age. High patellar displacement ratio measured on the lateral X-ray should draw the attention of possible patellar tendon avulsion.

Compliance with ethical standards

Conflict of interest The author declares that he has no competing interests.

Ethical approval The study was approved by the institutional review board.

References

1. Burkhart SS, Peterson HA (1979) Fractures of the proximal tibial epiphysis. J Bone Joint Surg Am 61:996–1002
2. Mayba II (1982) Avulsion fracture of the tibial tubercle apophysis with avulsion of patellar ligament. J Pediatr Orthop 2(3):303–305
3. Frankl U, Wasilewski SA, Healy WL (1990) Avulsion fracture of the tibial tubercle with avulsion of the patellar ligament. Report of two cases. J Bone Joint Surg Am 72(9):1411–1413
4. Schiedts D, Mukisi M, Bastaraud H (1995) Fractures of the tibial tuberosity associated with avulsion of the patellar ligament in adolescents. Rev Chir Orthop Reparatrice Appar Mot 81(7):635–638
5. Uppal R, Lyne ED (2007) Tibial tubercle fracture with avulsion of the patellar ligament: a case report. Am J Orthop (Belle Mead NJ) 36(5):273–274
6. Swan K Jr, Rizio L (2007) Combined avulsion fracture of the tibial tubercle and avulsion of the patellar ligament. Orthopedics 30(7):571–572
7. Kaneko K, Miyazaki H, Yamaguchi T (2000) Avulsion fracture of the tibial tubercle with avulsion of the patellar ligament in an adolescent female athlete. Clin J Sport Med 10(2):144–145
8. Clarke DO, Franklin SA, Wright DE (2016) Avulsion fracture of the tibial tubercle associated with patellar tendon avulsion. Orthopedics 39(3):e561–e564
9. Ogden JA, Tross RB, Murphy MJ (1980) Fractures of the tibial tuberosity in adolescents. J Bone Joint Surg Am 62(2):205–215
10. Little RM, Milewski MD (2016) Physeal fractures about the knee. Curr Rev Musculoskelet Med 9(4):478–486
11. Ehrenborg G, Engfeldt B (1961) The insertion of the ligamentum patellae on the tibial tuberosity. Some views in connection with the Osgood–Schlatter lesion. Acta Chir Scand 121:491–499
12. Kramer DE, Chang TL, Miller NH, Sponseller PD (2008) Tibial tubercle fragmentation: a clue to simultaneous patellar ligament avulsion in pediatric tibial tubercle fractures. Orthopedics 31(5):501